ARMY TACMS BLOCK II PAYLOAD SECTION DEVELOPMENT

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Abstract

The Army TACMS Block II missile was developed to carry and dispense thirteen brilliant anti-armor (BAT) submunitions. This system provides the Army with a deep strike capability against moving armor. This paper presents the development of the missile's warhead and its key subsystems. Unique interface issues associated with the integration of the BAT submunitions are highlighted. Ground and flight test results are presented to demonstrate the success of the design. The first end to end flight test with a live BAT submunition resulted in a successful missile flyout and submunition dispense, followed by BAT acquisition, tracking and kill of a moving armored vehicle.

Introduction

The Army Tactical Missile System (TACMS) Block II missile was developed to carry and dispense thirteen brilliant anti-armor (BAT) submunitions. This weapon system provides the Army with a deep strike capability to delay, destroy and disrupt advancing armor prior to its entry into battle. BATs are acoustic and infrared terminally guided submunitions that autonomously locate, home on and kill moving armored vehicles. Figure 1 shows a BAT in its stowed configuration, as carried by the missile, and a BAT in the fully deployed configuration. BAT was developed by Northrop Grumman Electronic and Systems Integration Division.

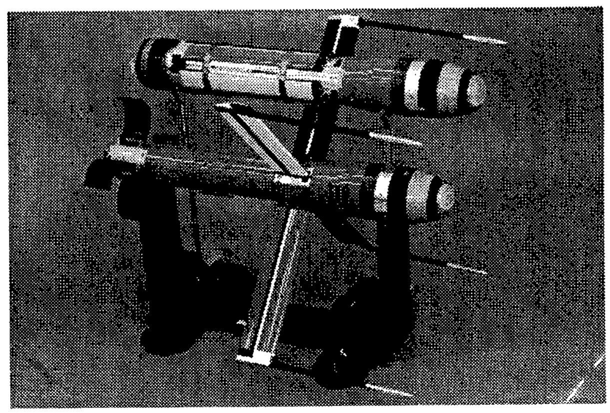


Figure 1. Brilliant Anti-Armor Submunition (BAT)

The Block II program began in August 1990 with a three phase series of Preliminary Development Studies. These led to the Continued Development(CD) program that was awarded in July 1995. An IOT&E option was added in March 1998, extending the contract until July 2000. A summary program schedule is presented in Figure 2.

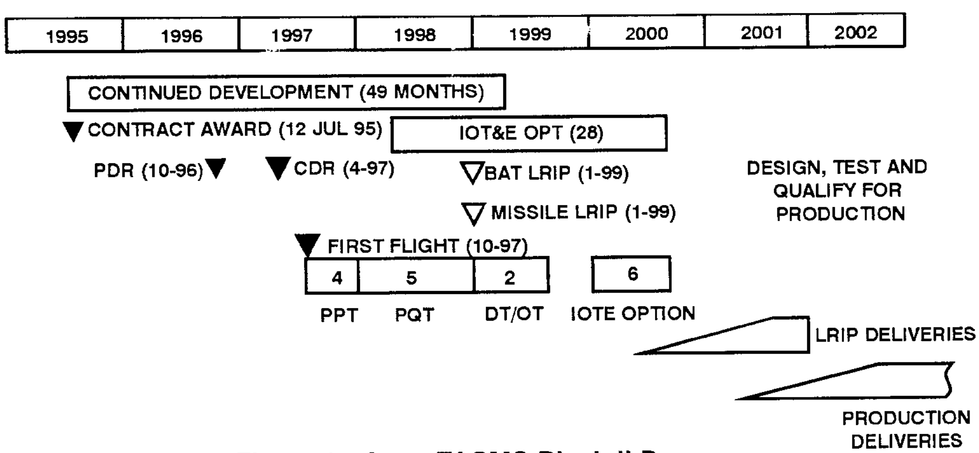


Figure 2. Army TACMS Block II Program

The Block II missile adds a heavy armor capability to the existing Block I and IA configurations, Figure 3. The Block II missile has essentially the same performance as Block I. In the future, a Block IIA configuration will be developed with similar performance to the IA missile. Figure 4 highlights the Block II unique features. Everything forward of the rocket motor is new for Block II except for the Improved Missile Guidance Set (IMGS). The IMGS was developed for the Block IA missile. For Block II, two new cards were added to the IMGS for controlling communications with, and dispense of, the BAT submunitions. The telemetry and flight termination system (TM/FTS) share a wrap around antenna that replaces seven Block I antennas. The GPS antenna was revised to match the contour of the Block II missile. The Sequencer Interface Unit (SIU) serves as the interface between the IMGS and the submunitions and the Submunition Interface Board (SIB) has the connectors for the BAT umbilicals. This paper focuses on key aspects of the development, analysis and testing of the Skin Separation system and the Submunition Dispense System.

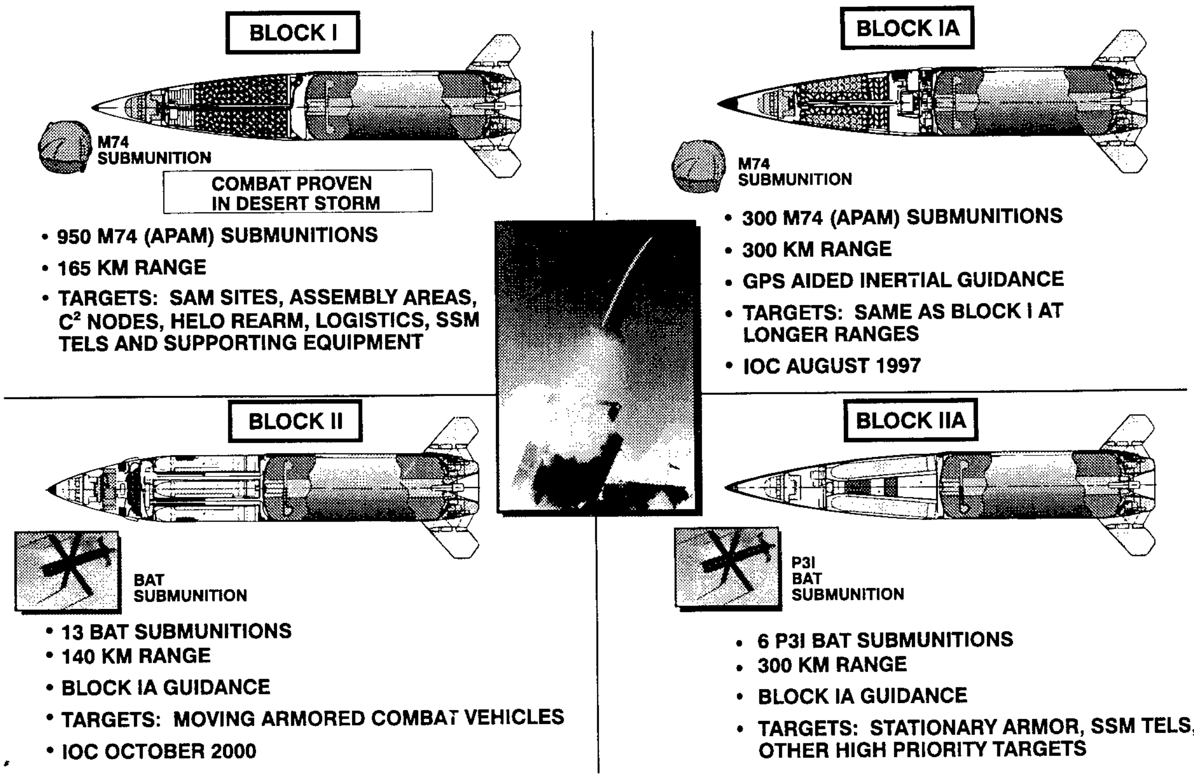


Figure 3. Army Tactical Missile System (Army TACMS) Capabilities

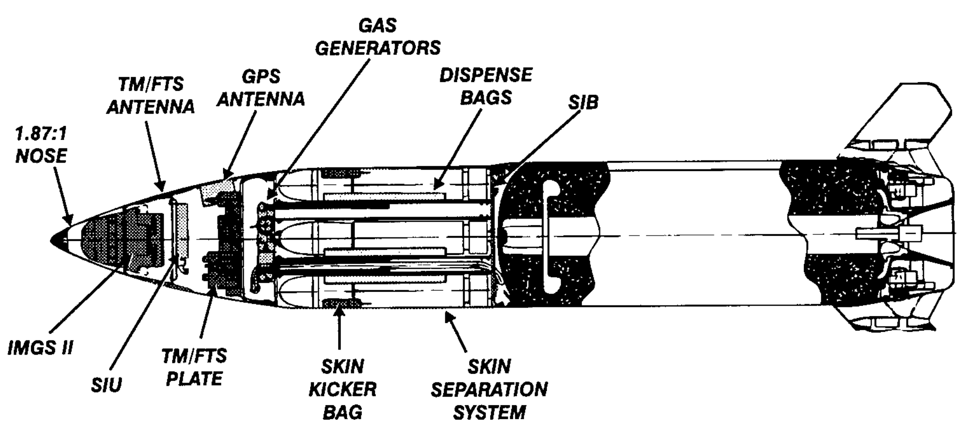


Figure 4. Army TACMS Block II New Features

Submunition Dispense System

The submunition dispense system (SDS) consists of the structure to carry the thirteen BAT submunitions and the hardware required to dispense (eject) the submunitions into the airstream. The structure was developed by Lockheed Martin Vought Systems and the dispense related items by Talley Defense Systems.

Payload Section Description

Figure 5 presents a general layout of the payload section. The payload section is a cylindrical section, except for the forward 9.25 inches, which is contoured to the von Karman nose shape. The structure is composed of two bulkheads connected by two single form and one dual form extrusions. Extrusion cross section can be seen in Figure 6. Hollow areas in the single form and dual form extrusions are used to route electrical harnesses and the dispenser plenum down tubes. There are two longitudinal channels that the skin panel sections attach to and that also hold part of the Skin Separation Subsystem (SSS).

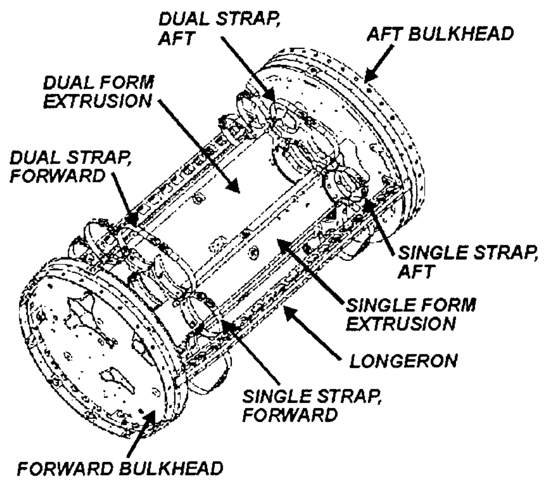


Figure 5. Payload Section General Layout

Requirements

Ideally the missile and submunition would be developed together or in parallel. This approach facilitates development from a weapon system standpoint. Issues can be resolved at the system level, where it often makes the most sense or is most cost effective. This ideal approach was not available for integrating BAT into the Block II missile. The BAT program was well into its EMD phase and this made changes to the submunition costly. The approach taken by Lockheed Martin Vought Systems was to minimize the impact on the BAT and try and resolve problems with missile solutions wherever possible. Thus BAT interface requirements became significant drivers in some of the missile's subsystem development.

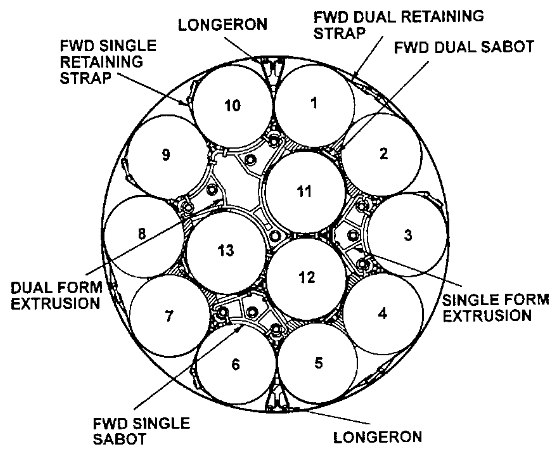


Figure 6. Payload Cross Section

BAT requirements associated with the SDS design are presented in Table 1. Because of the missile flow field interaction with the BATs as they are dispensed, these could not be passed directly to the dispenser. Evaluation of this interaction led to a series of wind tunnel tests to define the flow field around the Army TACMS missile. Additionally, there was a significant amount of computational fluid dynamic analysis performed to fill out the wind tunnel database. A six-degree of freedom simulation was developed to model and evaluate the effects of the flow field on the BATs. A good description of the analysis, testing and simulation of the flow field can be found in Reference 1.

After flow field effects were modeled and analyzed, the requirements of Table 2 were established and passed to the SDS developer. The revised pitch and yaw rate requirements reflect the flow field effect on these rates following dispense as well as angle of attack. The mean pitch rate, 65 d/s, is submunition nose out. Radial dispense angle was added to ensure maximum separation of the submunitions. Minimum dispense velocity constrains the time spent in the flow field and therefore minimizes the effect of the flow field on

the submunitions. In fact, the most difficult aspect of dispenser system development was obtaining an acceptable balance between the low-end performance constraint, minimum ejection velocity, and the upper-end constraint, maximum acceptable acceleration.

Table 1 BAT Imposed Requirements

Pitch, roll, yaw rate	750 d/s
Acceleration (disp. Axis)	150 g
Angle of attack	45 deg

Table 2 SDS Derived Requirements

Pitch rate	65 +/- 150 deg/sec
Yaw rate	0 +/- 90 deg/sec
Roll rate	750 deg/sec
Acceleration	< 150 g
Angle of attack	< 45 deg
Angle between BATs at dispense	36 +/- 10 deg
Minimum disp. velocity	>50 ft/sec

During the CD program, changes to the BAT resulted in a relaxing of its rate requirements from 750 d/s to 3000 d/s in all three axes. This did not occur in time to impact the dispenser design. The change to roll rate would have provided the most relief because the angle of attack limit constrains the amount of acceptable pitch and yaw rate. Every effort was made to design to the requirements of Table 2. Ground test results were evaluated against the requirements of Table 2. However, the dispenser performance in flight was judged against the more relaxed BAT level rate requirements.

Phase III Dispense Results

The three phase Preliminary Development Series, Figure 2, was a key element in the success of the Continued Development Program that followed. By the end of Phase III a near-tactical dispenser had been developed and tested at Talley Defense Systems. These tests were significant in that they provided a baseline design from which to start the CD effort; but more significantly, they highlighted some problem areas with the dispenser concept. This allowed problem solving to begin right away, once the CD contract was in place, and significantly reduced dispenser development time.

There were two proof of principle tests at the end of the Phase III program. For all dispense testing, the payload section was suspended between two poles as shown in Figure 7. A typical outer ring dispense event is shown in Figure 8. These tests indicated there were three issues that needed resolving; lack of radial symmetry, excessive roll rate of the dual strapped submunitions and excessive dispense acceleration.

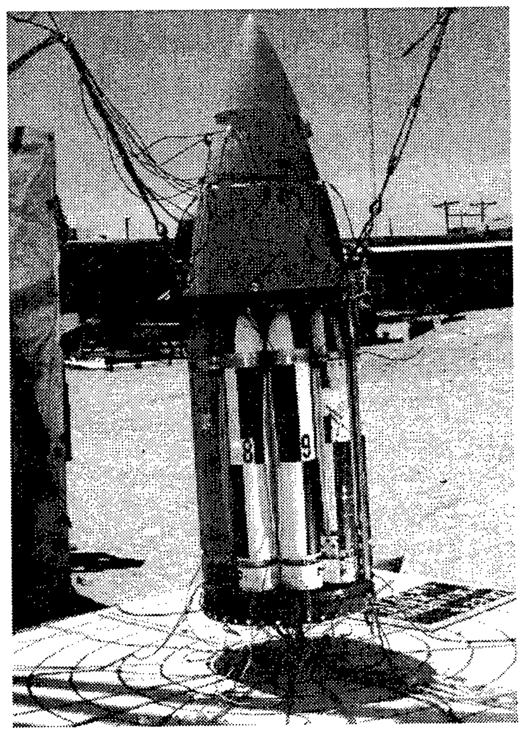


Figure 7. Setup For Dispense Testing at Talley Defense Systems

Figure 9 presents the angles between the submunitions as they are dispensed. Ideally there should be 36 degrees between each submunition and its neighbors. These data indicated that submunitions in the dual strapped locations (2&3, 5&6, 9&10) were being forced together. A loadout convention for the Phase III testing is presented in Figure 10. The dual strapped locations occur where two outer ring submunitions are over each of the inner ring submunitions. These two outer ring submunitions share a common pair of retention straps because there is no place to anchor individual straps.

Tip-off rates, as the submunitions come off the dispense bags, are summarized in Figure 11. Some submunitions were not instrumented, hence the missing data. Of particular note are the roll rate

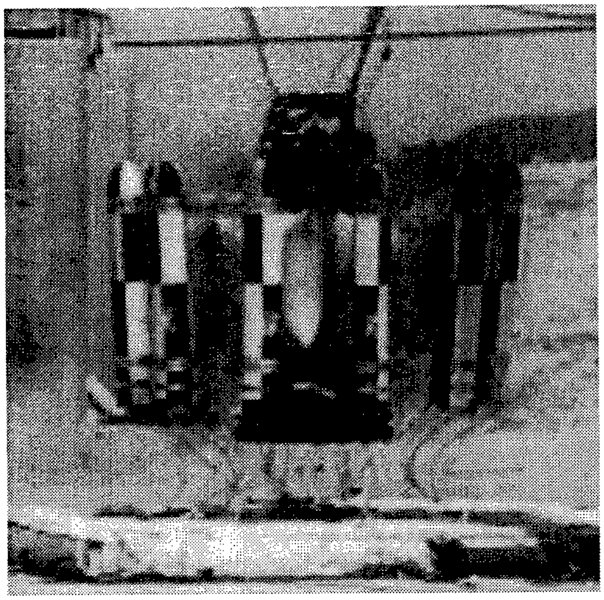


Figure 8. Outer Ring Dispense

results. The high roll rates are associated with the locations where the two submunitions share a set of straps. These locations are the same ones noted above where the submunitions tended to come together. Pitch and yaw rate data was limited but indicated excellent control of tip-off about these axes.

Figure 12 summarizes the dispense accelerations. There is quite a bit of scatter as well as several exceedances of the 150 g requirement. This was not considered to be a significant issue at

Bay No.	Separation Angle (Degrees)	
	Test 1	Test 2
1 to 2	40.5	40.5
2 to 3	26.0	26.0
3 to 4	47.5	47.5
4 to 5	41.0	41.0
5 to 6	24.5	24.5
6 to 7	41.0	41.0
7 to 8	39.5	39.5
8 to 9	45.0	45.0
9 to 10	26.5	26.5
10 to 1	38.5	38.5
11 to 12	111.0	106.5
12 to 13	142.0	146.0
13 to 11	106.5	107.5

Figure 9. BAT Dispense Separation Angle Comparison, Phase III Testing

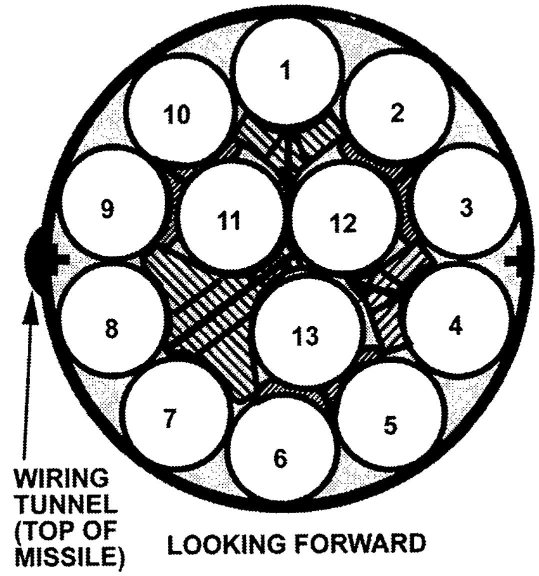


Figure 10. Phase III Loadout Convention

this point because the gas generator had not been optimized. As discussed later, this turned out to be not so simple in that it ended up involving the retention straps and the BAT structural response as well as the gas generator.

Resolution of Dispense Issues

To aid in understanding the mechanics of dispense, the MSC DYTRAN computer code was acquired. This code has been used extensively in the automobile industry to model air bags and their inflation characteristics. Our use was to model the dispense bags, the straps, the submunitions and surrounding structure. To do this analysis, we used MSC DYTRAN in conjunction with MSC NASTRAN. Figure 13 presents typical results from the DYTRAN analysis for both single and dual strapped submunitions. Component trajectories were generated that provided positional insight as well as angular rates and displacements. These studies proved quite successful in matching the dispense environment.

Results from the MSC DYTRAN analysis revealed that the region under the dual strapped BATs presented a different volume for the bag to expand into than under the singles. This resulted in enough mismatch in the expanding bags of the outer ring to create asymmetries. It was determined that a key to obtaining the desired dispense characteristics was near-symmetrical interaction between the expanding bags.

Bay No.	Roll (Degrees/Second)		Pitch (Degrees/Second)		Yaw (Degrees/Second)	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1	508	461	*	*	-10.1	14.9
2	-1152	-1901	18.3	-25	0	20
3	947	562	*	*	*	*
4	-407	-259	*	-14.9	*	*
5	508	-119	13.1	*	*	*
6	914	940	*	*	*	*
7	-338	-839	18.3	*	*	*
8	796	641	*	50	*	*
9	-371	-79	30.3	14.9	27.4	*
10	1757	1480	0	80	*	-50
11	403	72	42.3	75	*	*
12	40	126	70	112.3	*	*
13	-101	-61	60.6	62.2	*	*

Figure 11. BAT Tip-Off Rate Comparisons, Phase III Testing

Bay No.	Acceleration(g's)	
	Test 1	Test 2
1	200	*
2	180	*
3	*	130
4	180	120
5	*	*
6	153	123
7	*	*
8	170	140
9	170	140
10	130	130
11	*	*
12	127	100
13	*	*

* No data

Figure 12. BAT Dispense Accelerations Comparisons, Phase III Testing

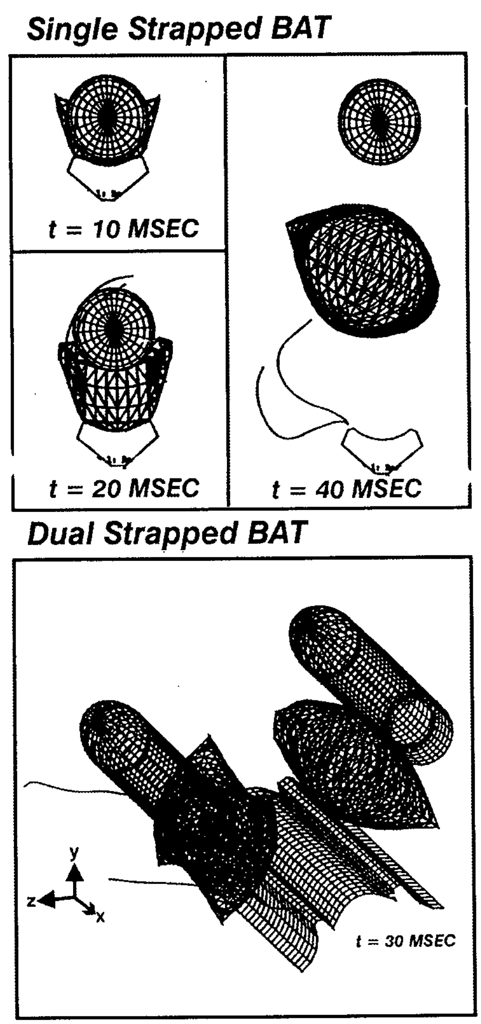


Figure 13. MSC Dytran Analysis

Three pieces of filler material were added to the inner ring submunition cover plate, Figure 14, to fill up the excess volume. Dispense tests following this modification resulted in a more uniform radial pattern, Figure 15, and brought the roll rate of the duals in line with the other locations, Figure 16. This one simple modification, predicted by the DYTRAN code, resulted in a solution for two of the three issues to come out of the Phase III testing.

At this point the remaining issue was to reduce the dispense acceleration to an acceptable level. Phase II testing demonstrated that submunitions could be dispensed using a gas bag and passive

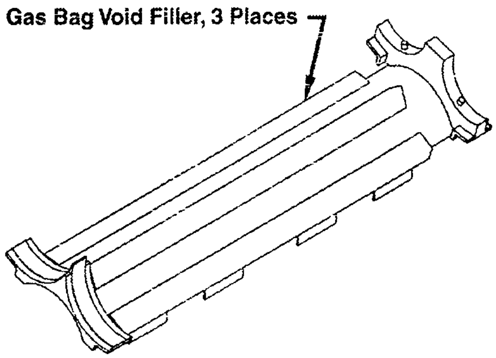


Figure 14. Gas Bag Void Filler

release system. During this time, the primary emphasis was to develop a dispense system that would give the BAT an outward velocity of 50 ft/sec.

Phase III and the CD program presented additional challenges to the dispense system to reduce acceleration to the levels which would be compatible with established BAT system design criteria. The effort then became centered around determining which parameters influenced dispense acceleration the most and to find ways to reduce them.

Bay No.	Average Separation Angles(Degrees)			
	Tuning & Performance (6 Tests)	Risk Reduction (7 Tests)	Static Ejection (3 Tests)	Requirements
1 to 2	33.5	34.4	33.4	36+/-10
2 to 3	35.3	34.9	41.0	36+/-10
3 to 4	34.3	35.0	35.0	36+/-10
4 to 5	35.3	33.6	34.9	36+/-10
5 to 6	37.5	39.3	39.6	36+/-10
6 to 7	38.0	38.5	38.4	36+/-10
7 to 8	31.5	31.1	31.0	36+/-10
8 to 9	33.8	35.6	36.3	36+/-10
9 to 10	40.5	40.6	36.5	36+/-10
10 to 1	38.8	36.1	40.3	36+/-10
11 to 12	106.5	105.0	107.5	108+/-10
12 to 13	103.3	111.0	116.5	108+/-10
13 to 11	150.0	144.3	136.0	144+/-10

Figure 15. BAT Dispense Separation Angle Comparisons, After Adding Filler Material

Bay No.	Roll Rate (Degrees/Second)		
	Tuning & Performance (6 Tests)	Risk Reduction (7 Tests)	Static Ejection (3 Tests)
1	136	421	197
2	689	766	507
3	*	217	644
4	305	362	806
5	*	118	1013
6	543	564	747
7	*	194	275
8	666	550	580
9	*	316	427
10	339	491	523
11	*	562	416
12	35	148	144
13	*	729	385

* No Data

Figure 16. BAT Dispense Roll Rate Comparisons, After Adding Filler Material

An initial investigation which simulated the dispense event using a Northrop Grumman supplied Finite Element Model determined that the response acceleration of the BAT had the characteristics shown in Figure 17. This acceleration is in the form of an envelope of the absolute maximums of the real time acceleration response time histories at each degree of freedom along the body of the BAT. Several observations are apparent from the response envelope. The first is the shape of the envelope which indicates that the response is in the first bending mode where the nodes are at stations 9.0 and 28.0 inch (acceleration expressed in absolute value gives the envelope a bat wing shape rather than the typical 1st beam bending mode shape). Secondly the rigid body portion of the acceleration as seen at the nodes is about 80% of the total acceleration. Additional analysis and test data indicated that while the magnitude of the bag force influenced

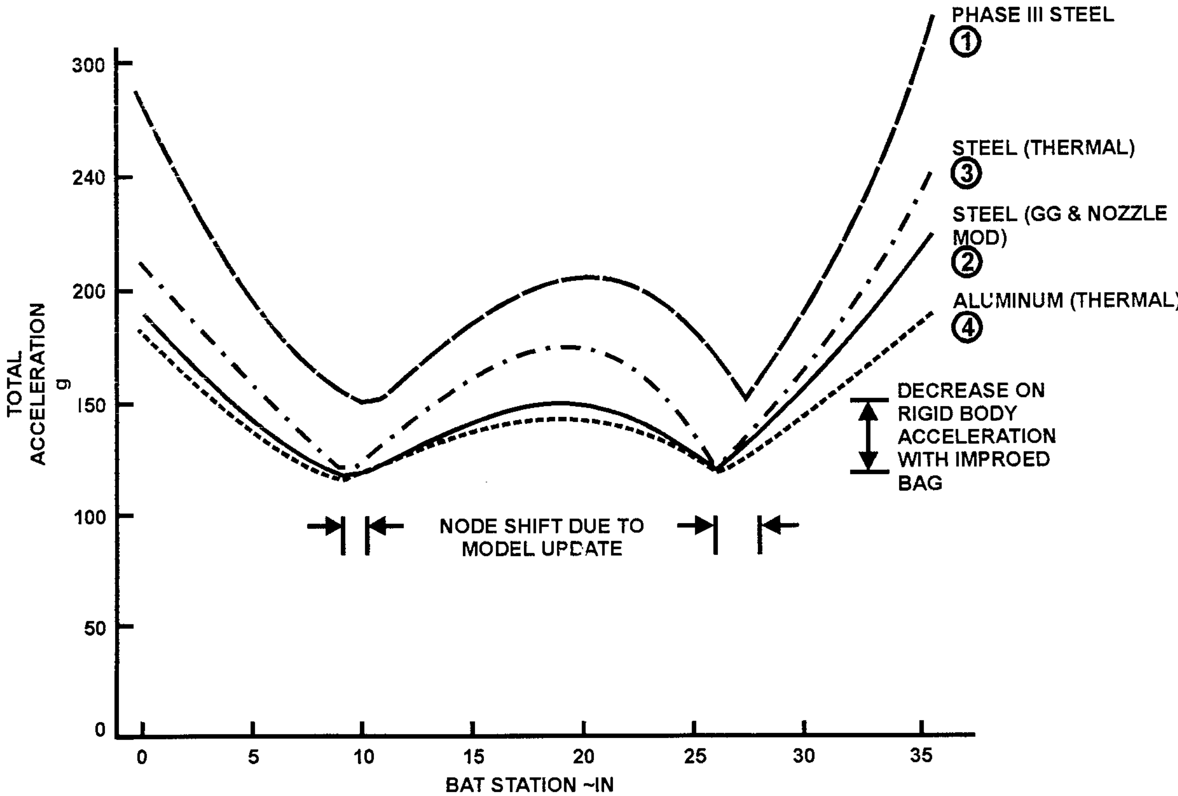


Figure 17. Envelope of Maximum BAT Acceleration Due to Dispense

both the rigid and elastic body acceleration, the strap break strength influenced only the elastic body acceleration. Steps were taken to reduce the dispense acceleration by both reducing the magnitude of the force imparted by the gas bag and to reduce the break strength of the straps to the absolute minimum required to retain the BATs during exposure to all induced loading conditions. The magnitude of the bag force was reduced by changing the [illegible]ng of the flow through the nozzles at the bag manifold interface so that the overall impulse and therefore the ejection velocity remained the same but the peak force was reduced as shown in Figure 18. Minimum strap break requirements were established by determining the minimum preloads required to keep the BATs seated on their sabots during maximum induced loading conditions. Incorporating these improvements the response acceleration was reduced as shown in Figure 17 by response no. 2.

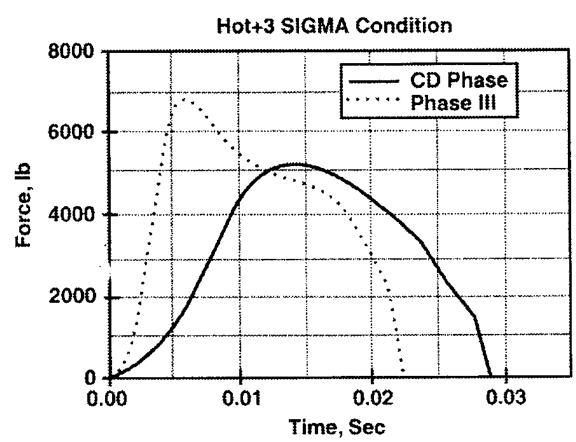


Figure 18. Bag Force Profile Shaping

As better estimates of the thermal environment became available it was determined that the strap preloads would need to be increased to account for the relative difference in expansion and contraction of the steel straps and the aluminum BATs. The impact of increased break strength on dispense acceleration is shown in Figure 17 response no. 3. The increase in acceleration was enough to drive the strap material to aluminum, which was more compatible with the BAT material. The change in material presented a challenge to develop a different way in defining the break point in the strap other than a notch. For certain straps the width of the notch was too wide relative to the strap width. The greater notch width not only resulted in erratic loads required to break the notch, but also caused yielding within the notch itself under preload. It was believed this

would cause creep and loss of preload over time. Losing preload was considered unacceptable since analysis showed that higher dynamic loads in the straps would occur if the BATs could not remain seated on their sabots. At about the same time, it was determined that a way needed to be found to release the outer ring straps to avoid interference with the dispense of the inner BATs. Resolution of both issues came with the development of the cleated slot as shown in Figure 19. The cleat allows the unbroken end of the strap to release after the strap breaks. The breakside slot, which uses edge distance rather than notch width to determine the break strength, has enough end length to avoid local yielding. With these improvements, the SDS was able to meet all its requirements as shown by Figure 17 response no. 4. There were some BAT locations at the nose and tail where the response envelope was above 150g, but there are no critical components in these locations that were adversely affected by the acceleration level.

In total, there were 16 dispense tests conducted at TDS during the development of the dispenser. The last four were conducted with the final tactical configuration for warhead qualification. Figure 20 presents the cumulative probability of dispense acceleration at the BAT center of gravity based on the results of the warhead qualification tests. Cumulative probability data for the ejection velocity is shown in Figure 21. A summary of the tip-off rates is presented in Figure 22. These data confirm the success of the dispenser design.

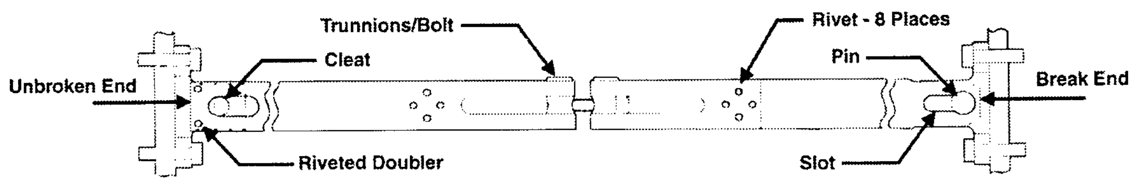


Figure 19. Cleat and Slot Arrangement

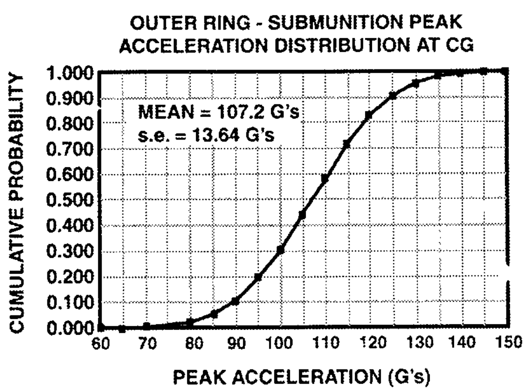


Figure 20. Cumulative Probability of Dispense Acceleration

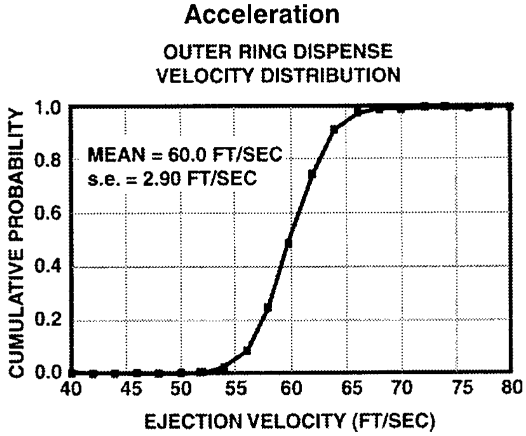


Figure 21. Cumulative Probability of Dispense Velocity

Roll Rate (Degrees/Second)			
Bay No.	Roll (Deg/Sec)	Pitch (Deg/Sec)	Yaw (Deg/Sec)
1	197	-45	-4
2	507	5	-29
3	644	-29	*
4	806	-73	-37
5	1013	-69	43
6	747	-45	*
7	275	*	*
8	580	-51	-14
9	427	-36	-69
10	523	-80	*
11	416	-111	62
12	144	-52	*
13	385	-29	-147

Pitch - "-" = Nose Out Rotation
Yaw - "+" = Nose Right Rotation (Looking Inboard)
Roll - "+" = Clockwise Rotation (Looking Aft)
"*" - No Data

Figure 22 Static Ejection Test Series Tip-Off Rates

Skin Separation System

The purpose of the SSS is to rapidly separate the two skin panels that cover the payload section and position them such that they are carried away by the air stream without impacting the missile or the submunitions.

The initial concept selected for Block II was based on the Block I and IA missile designs. These used a Flexible Linear Shaped Charge(FLSC) explosive cutter around the forward and aft bulkheads and along the longerons. Along the longeron the explosive cuts a splice plate that joins the skin panels, Figure 23. For Block I and IA, the skin is separated into 3 separate panels and removed by centripetal force. These missiles spin up in order to remove the panels and dispense the bomblet payload. The Block II missile was designed with two skin panels because there was only enough space for two longerons. It was undesirable to spin the missile at dispense so skin kicker bags were added to force the skin panels out into the air stream. The Block II concept is presented in Figure 24. The skin kicker bags are inflated by small gas generators attached to the skins and are timed to inflate when the skins are separated.

During the Phase III program, an element test fixture, Figure 25, was developed to evaluate skin severance charges and subcontractors. It became apparent during the element testing that the pyroshock levels resulting from the explosive charges were too high for the BAT. Different charge levels were examined, but even the minimum charge that severed the skin produced too much shock. FLSC also exposed the BATs to flame and hot particles and there was not enough space for suitable protective covers for the BATs. One vendor used a frangible foam backing material to hold the FLSC. This significantly reduced the pyroshock but the frangible foam material produced substantial debris, causing concern that this might interfere with the BAT. This concept was also discarded. As Phase III was winding down, there was not an acceptable method for cutting the skin.

It was during this time that Lockheed Martin Vought Systems was approached by a vendor with an alternate mechanical concept. He had been doing testing with steel tubes that had been flattened. When the tubes were pressurized they would return to their rounded state. He proposed using the energy of the tube stroke to fracture bolt heads retaining the skin. A proof of principle test using the element test fixture indicated the feasibility of this concept. The test demonstrated successful separation of the skin and pyroshock levels were also reduced as shown in Figure 26.

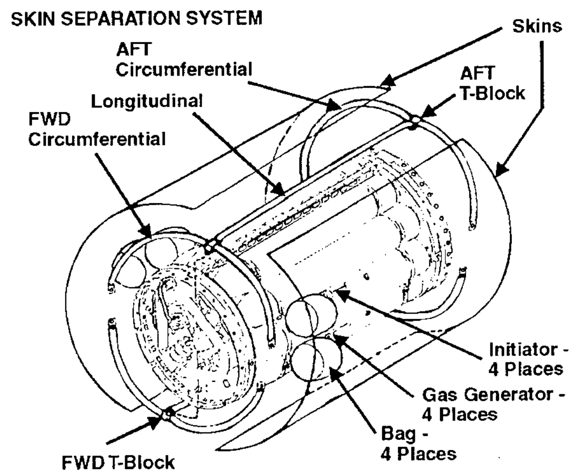


Figure 24. Skin Separation System Assembly

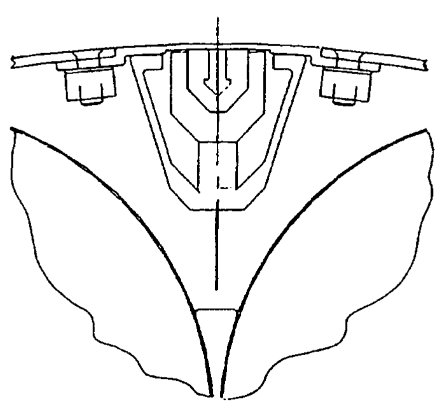


Figure 23. Block I, IA Skin Separation Concept

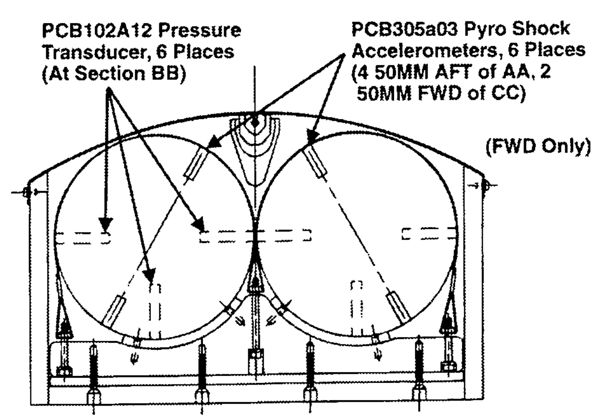


Figure 25. Skin Severance Element Test Fixture

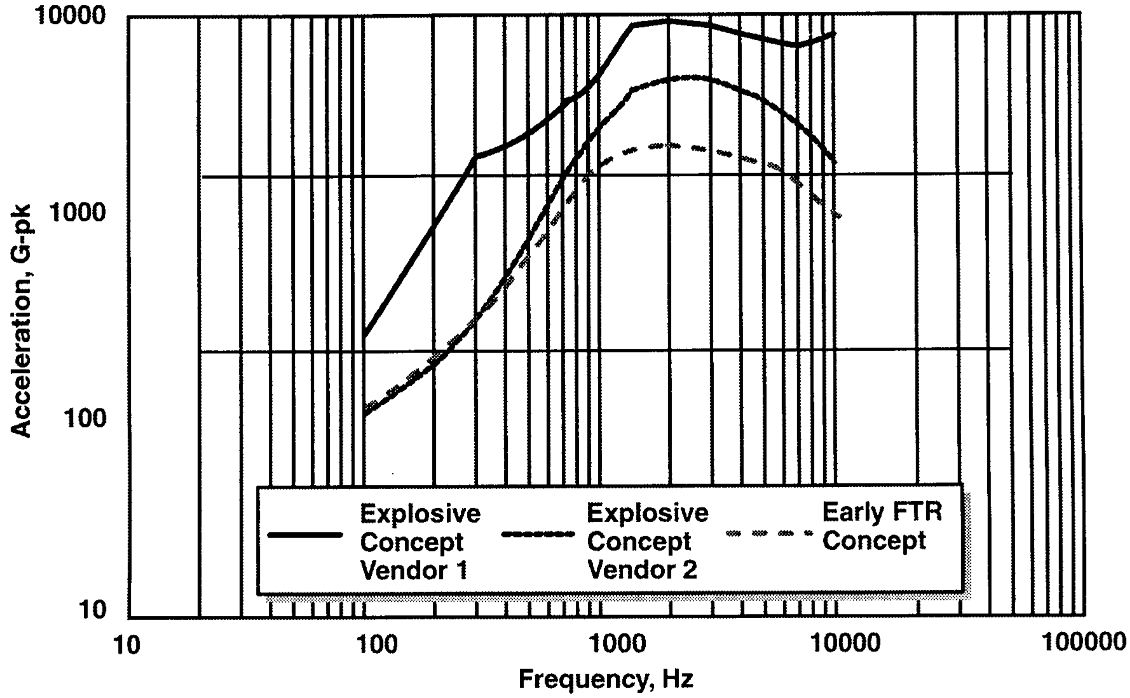


Figure 26. Pyroshock Comparisons

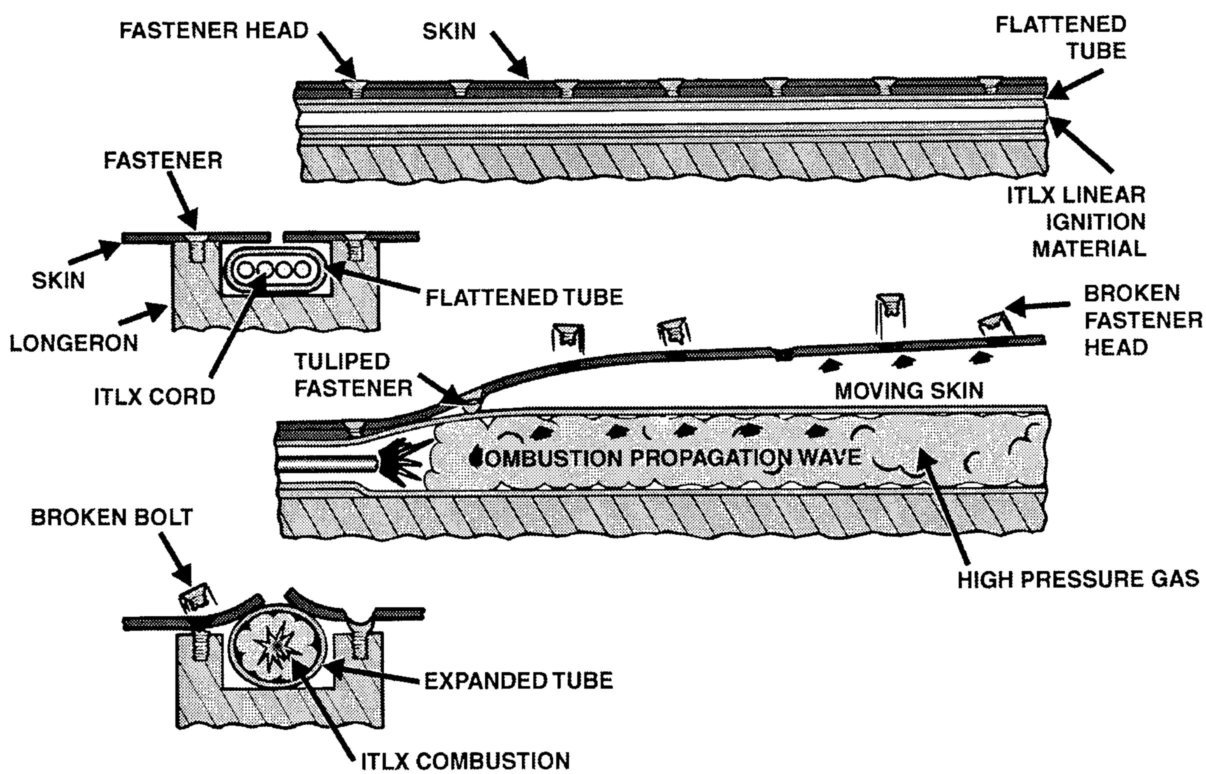


Figure 27. FTR Skin Separation

Two vendors provided bids for development of this flat to round(FTR) tube concept. Eventually, there were three concepts from the two vendors that were evaluated. Each method failed bolts as required but there were differences.

The first concept had a gas generator that fed directly into the tubes(s). The main drawback to this configuration was the length of time it took to inflate the length of tube needed for the Block II application. The skin panels should separate as quickly as possible to prevent the air stream from causing uneven separation or even tearing of the skin panel. Five milliseconds was selected as the acceptable upper limit. For comparison, explosive severance of the skins occurs in approximately 0.5 ms. Concept one took 40 ms to 50 ms which was considered unacceptable.

The second concept was similar except the gas generator vented into a small plenum. A rupture disk failed at a predetermined pressure resulting in a pressure wave traveling through the tube, opening the tube as it went. This approach resulted in a separation time of 12 ms to 15 ms. This was an improvement but was still too long. This approach also had a bad habit of rupturing the tubes at their ends.

A third concept inserted ITLX (a pyrotechnic ignition cord produced by OEA) into the flattened tubes. When ignited the burning cord generated the gas to expand the flattened tube. This is shown schematically in Figure 27. This concept proved to be quite successful, since the total action time was reduced to 2 ms. Talley Defense Systems was selected to provide it for the Block II missile.

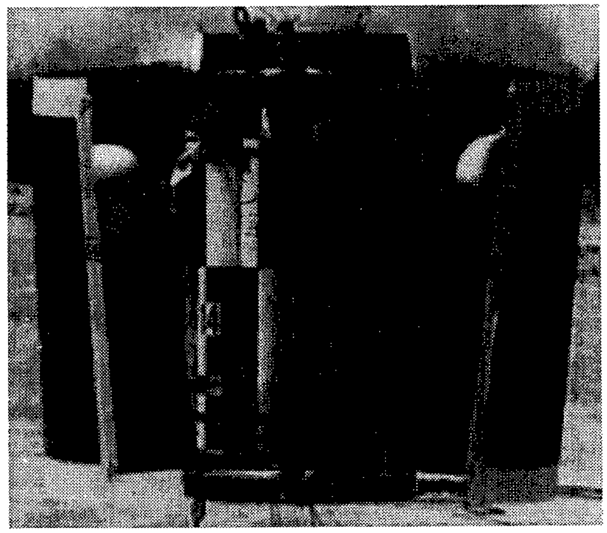


Figure 28. Skin Separation Test

This concept was thoroughly tested at the bench level and at the payload level. Figure 28 shows a typical skin separation event. The skin kicker bags can be seen as they inflate to move the skin away from the payload.

Selected Test Series and Lessons Learned

This section focuses on selected tests that were instrumental in the development and validation of the SSS and SDS. The idea is to provide insight into the range of testing and some of the lessons learned; i.e., the benefits of the testing. It is not intended to be all inclusive. This section concludes with a comparison of dispenser performance from the flight testing that has occurred to date.

Skin Separation System Wind Tunnel Test #1

A full scale wind tunnel test was conducted to evaluate the skin separation system over the flight envelope. Mach number, angle of attack and timing delay between initiation of the SSS and the skin kicker bags were variables. Due to tunnel size constraints, only one skin panel was ejected. The tests were conducted at the Microcraft Wind Tunnel in Hawthorne, CA.

These tests confirmed that the SSS system would separate skin panels over the desired operating range. In each case, the skin kicker bags rotated the skin panel leading edge out where the air stream swept the panels away. An attempt to separate the skin without the skin kicker bags was unsuccessful. Skin separation was relatively insensitive to timing delay. A value of 3 ms was ultimately selected for flight.

Sled Test

A high-speed sled test was conducted to evaluate the skin separation and dispense characteristics at maximum dynamic pressure. The sled train configuration used two pusher sleds with five Honest John rocket motors ignited in three stages; two boost stages and one sustainer stage, and a sled containing the payload assembly. The sting with the payload section was attached to the sled pylon.

Payload weight constraints limited the number of submunitions that could be dispensed. Five submunitions were dispensed from the outer ring; two of which were mass simulants to balance the loads on the sled, and one from the inner ring. The dispensed simulants were # 1, 9, 10 and 11.

Skin separation, Figure 29, was good. The skin panels separated symmetrically with sufficient radial velocity to clear the missile tail fins. Outer ring dispense, Figure 30, was good except the cover plate over the inner ring submunition flew out and punctured the high-speed stabilizer on BAT # 10. This led to a redesign of the cover plate. Subsequent flight testing has confirmed the redesign. Also note in Figure 31 that BAT # 1 yaws nose out (away) from the center BAT, # 10. This flow field effect is partially due to the non-symmetrical BAT-to-BAT aerodynamic interference; i.e., there are no BATs outside # 1.

Inner ring dispense was as expected and no anomalies were observed. Subsequent reconstruction of the trajectory of # 11 indicated the flow field interaction with the BAT was close to what had been predicted from the wind tunnel results.

Shadow graphs, Figure 32, provided insight into the complex nature of the flow field. The shadow graphs indicated the presence of a shock off the forward circumferential FTR tube that had not been modeled in the wind tunnel tests. These photos also revealed the presence of a rather strong shock coming off the sled structure. This shock would obviously not be present in flight and its effect on the observed characteristics was unknown.

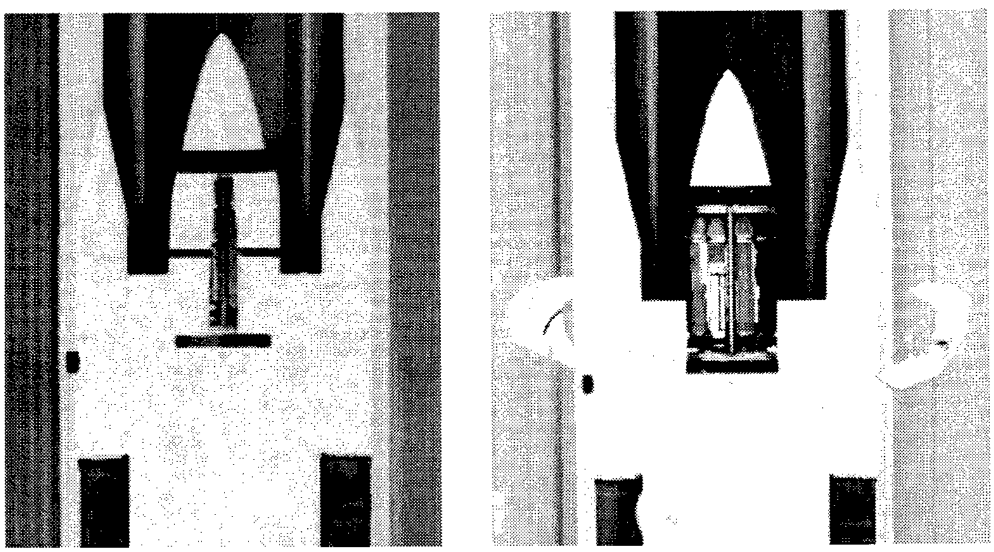


Figure 29. Sled Test Skin Separation

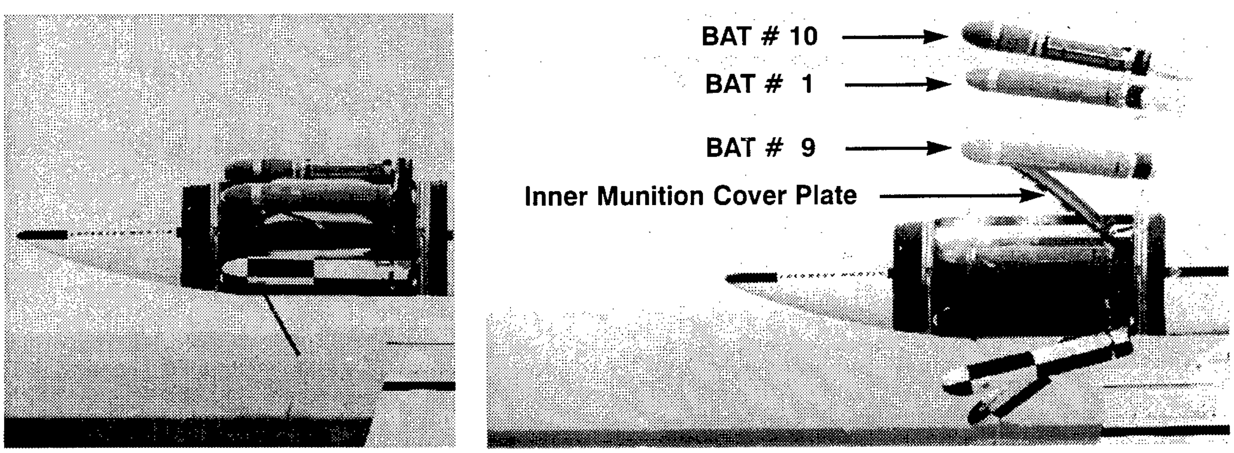


Figure 30. Sled Test Outer Ring Dispense

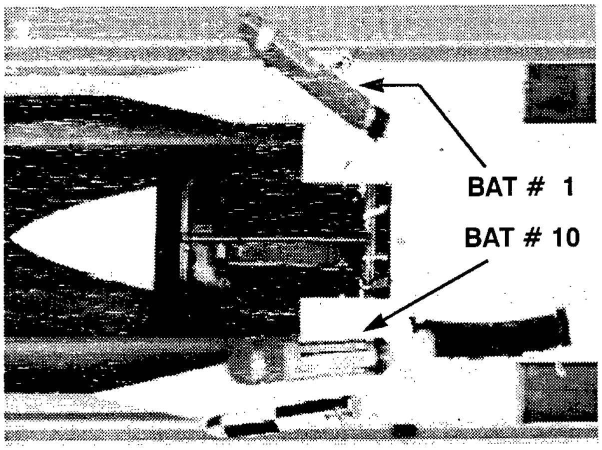


Figure 31. Outer Ring Dispense, Top View

Another lesson learned from the sled test was that the outer straps did not get blown away prior to inner ring dispense. This led to the decision to modify the outer straps so they would fall away after the outer ring dispense event. This eliminated the potential for the inner ring BATs to be damaged by the outer ring straps.

<u>Skin Separation System Wind Tunnel Test #2</u>

During static dispense testing of winged BAT simulants, it was discovered that the skin kicker bags were damaging the BAT wing release mechanism resulting in premature wing deployment. The BAT wing release cable terminates into a cutter in the body after passing thru a piece of dunnage on the fuselage, Figure 33. The kicker bags were reacting against the dunnage and creating a shear load. The only thing resisting this load was the wing deployment cable. This cable was failing under the load and releasing the wings.

There was a two pronged solution for this problem. Northrop Grumman modified the dunnage to provide a shear resistance capability and Lockheed Martin Vought Systems shortened the kicker bags to minimize the load on the dunnage. These modifications were then tested during the second entry into the Microcraft High Speed Wind Tunnel.

These tests confirmed that the changes to the BAT and the skin kicker bags solved the premature wing deployment problem. However, it was determined that at some flight conditions the kicker bags were causing additional problems as they were blown aft when exposed to the free stream

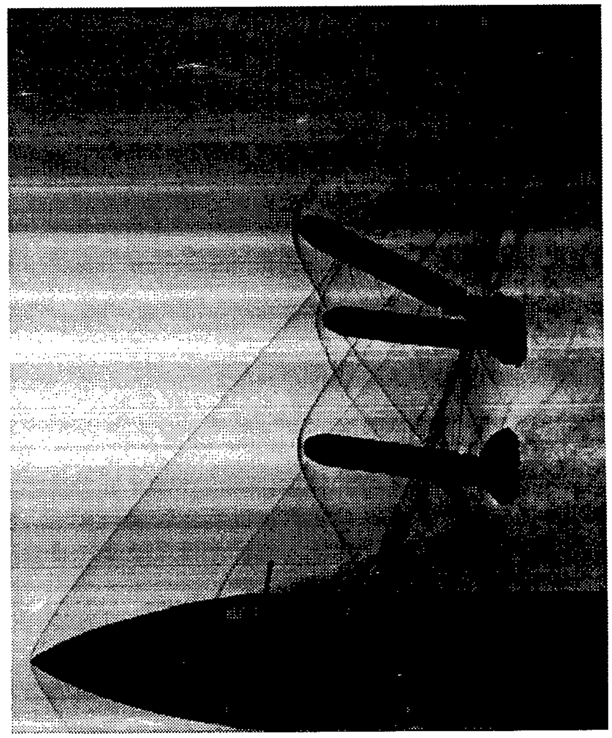


Figure 32. Sled Test Shadow Graph of Outer Ring Dispense

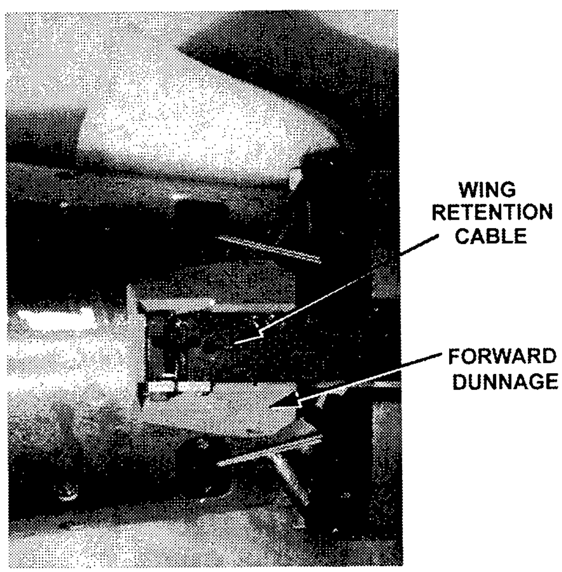


Figure 33. BAT Wing Retention Cable and Forward Dunnage

environment. As the skin panel rotated outward, a ram air effect was created that blew the kicker bags aft over the BATs. This resulted in damage to the BAT wing retention straps and/or the fin retention strap. This was solved by including nut plates in the kicker bags so they could be bolted to the skins. This ensures that the bags leave with the skins and do not impact the BATs.

Flight Tests

There have been two flight tests to date, the Engineering Development Test (EDT) flight and the Pre-production Proveout Test (PPT) flight #1.

The EDT flight was the first flight of the Block II missile. Its primary objective was to demonstrate the dispense of thirteen BAT simulants in flight. A load out is presented in Figure 34. The simulants with an "f" in the nomenclature have deployable wings and fins just like a tactical BAT. The others are smooth-bodied and represent the wings-folded packaging size. The inner ring was loaded with three Camera BATs developed by Lockheed Martin Vought Systems. Each of these simulants had a 600 frame/second camera on board to film the dispense and initial flight of the outer ring BATs.

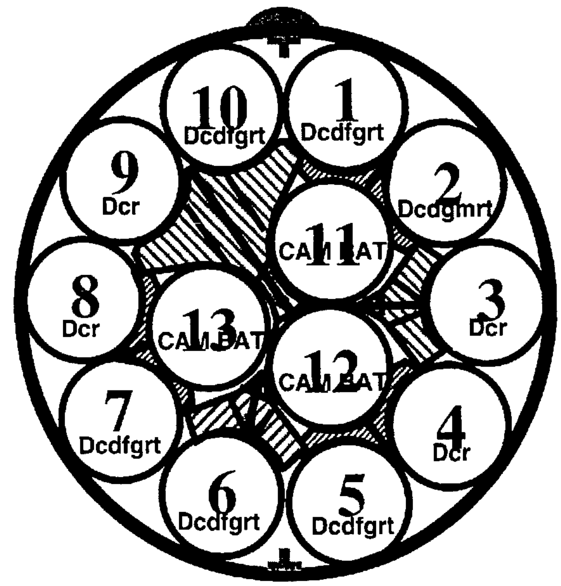
The skin separation event could only be monitored by the ground tracking cameras. These showed the skins separating symmetrically from the missile as expected.

The outer ring dispense event was very good. Figure 35 compares data from the instrumented simulants to the current System Interface requirements. Note that the rate requirements are at the BAT level (more rate allowed) and not those to which the dispenser was designed and ground tested. These data indicate that the dispenser performance was excellent.

The PPT-1 flight was similar to the EDT flight except a tactical BAT was carried in Location 5. The load out is shown in Figure 36. The tactical BAT carried a flight data recc-der in lieu of an explosive warhead. This flight was the first end-to-end test of the Block II missile with a tactical BAT. The missile was launched against a moving target array, flew to the appropriate dispense point, initialized and dispensed the BATs. The tactical BAT acquired, tracked and impacted one of the target vehicles.

Skin separation, as observed by the tracking cameras, appeared nominal.

Dispenser performance was excellent as it was for EDT. Figure 35 also presents PPT-1 comparisons with requirements.



SIMULANT DEFINITIONS
D = SIMULANT
T = TACTICAL
c = GIRAS/DSS
d = DC ACCELEROMETERS
f = WINGS AND FINS
g = INSTRUMENTED GYRO
m = MICROPHONE
r = TACTICAL UMBILICAL
t = FLIGHT DATA RECORDER

Figure 34. EDT Flight Test Loadout

Conclusion

A skin separation system and submunition dispense system have been developed for the Army TACMS Block II missile. These systems were developed through analysis, simulation and ground testing and have been successfully validated by flight test.

References

1. AIAA 98-0754 "Calibrating CFD Predictions for Use in Multiple Store Separation Analysis," Wooden, P. A., Brooks, W. B., and Sahu, J., 36th Aerospace Science Meeting and Exhibit, 12-15 January 1998, Reno, NV.

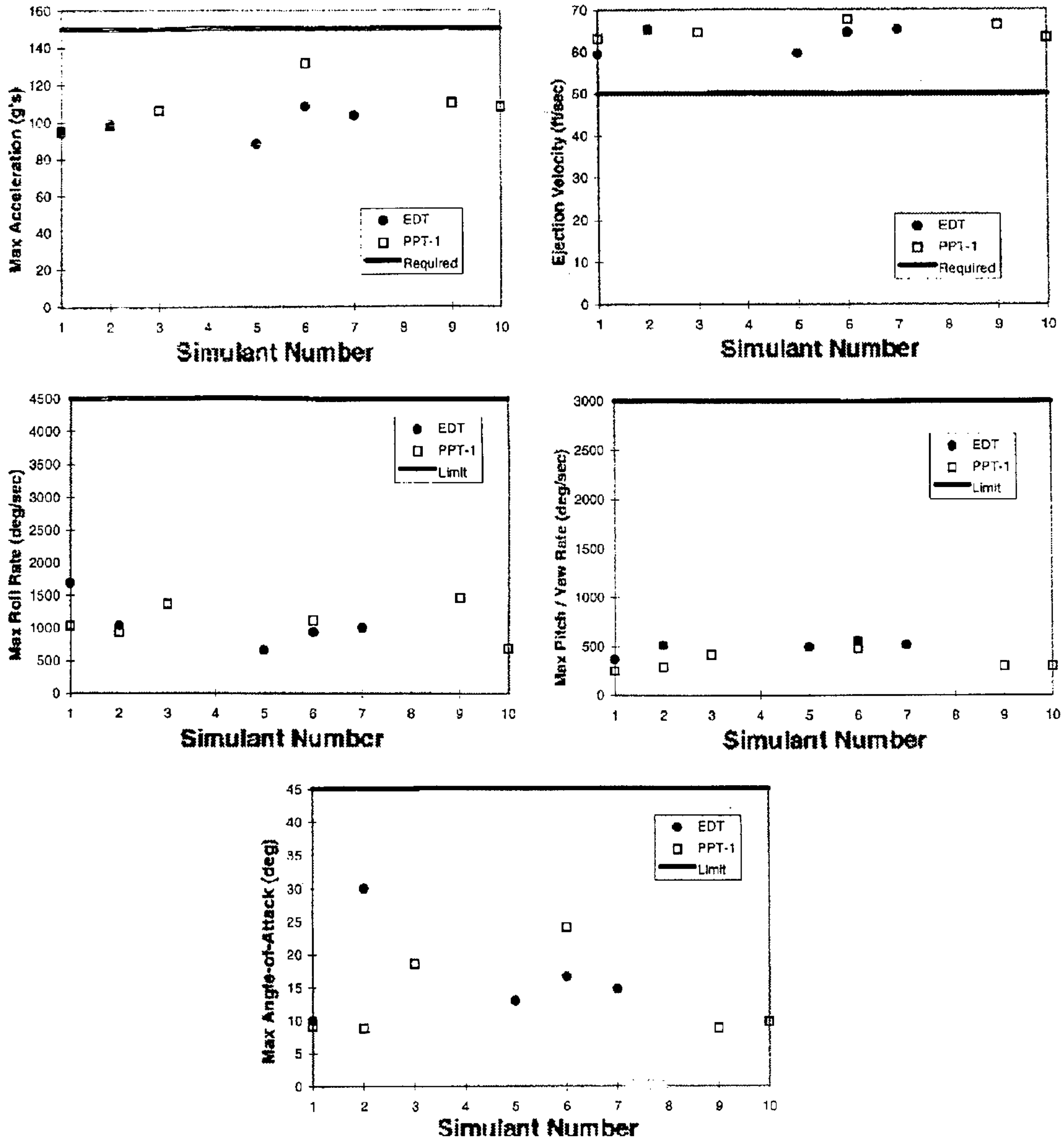


Figure 35. EDT Test Results

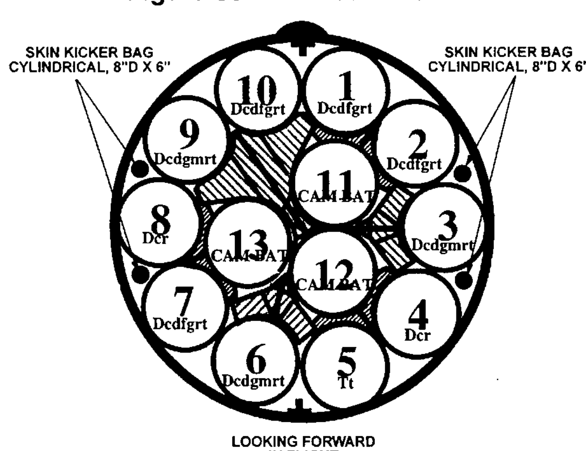


Figure 36. PPT-1 Flight Test Loadout

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